IGES Working Paper

Impact of the Increasing Number of Coal-Fired Power Plants on Japan's Mid- and Long-Term Reduction Targets

– Towards developing a framework for global warming mitigation measures for the entire power sector –

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<Summary>

On 17 July 2015, the Japanese government unveiled its Intended Nationally Determined Contribution (INDC) to reduce its greenhouse gas (GHG) emissions by 26% below FY 2013 levels by FY 2030 (25.4% reduction below FY 2005 levels). The government also approved the outlook for long-term energy supply and demand, which stipulates that in 2030 the share of nuclear power will be 20% to 22%, renewables will be 22% to 24%, and coal-fired power generation will be 26%.

At the same time, there is a large number of coal-fired power plant constructions currently being planned, the total capacity of which amounts up to 18GW. Unrestricted construction of coal-fired power plants may put Japan's long-term transition to a low-carbon economy at risk.

This paper analyses the potential impacts of recent construction or retrofit plans of coal-fired power plants with a total capacity of 18 GW (referred to as "the new coal-fired power plants" below) on Japan's mid-term and long-term greenhouse gas (GHG) mitigation targets. This paper also examines the economic impact on coal-fired power plants when effective carbon price is implemented in the entire power sector.

Comparative assessment of Japan's mid-term target (2030 target) and impact of plans for the coal-fired power plants

This study first compared the expected CO_2 intensity for power generation in 2030 under current policy plans for Japan, the United States (U.S.) and the European Union (EU). Under the planned electricity mix, the CO_2 intensity for power generation in 2030 is calculated to be 0.36 tCO_2/MWh. Although this is comparable to the CO_2 intensity in the U.S. under its Clean Power Plan (0.34 - 0.38 tCO_2/MWh in 2030), it is higher than that of 0.18 tCO_2/MWh in the EU. Power generation CO_2 intensity values in the U.S. and the EU will rapidly improve towards 2030 and will be within the range projected in 450 ppm CO_2e stabilization scenarios. By contrast, Japan's power generation CO_2 intensity expected for 2030 under the new electricity mix.

The currently planned coal-fired power plant constructions may bring in more coal-fired power than needed under the 2030 electricity mix plan, Under the planned 2030 electricity mix, the amount of electricity generated by coal-fired power plants is calculated at 277 TWh, with

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CO_2 emissions estimated at 244 $MtCO_2$. However, if plans for the new coal-fired power plants with a total capacity of 18 GW are implemented, the total amount of power supplied from coal-fired power generation in 2030 will be 338 TWh or 32% of the amount of power supplied from all power sources, which will exceed the target of 26% in the 2030 electricity mix. CO_2 emissions are calculated at 291 $MtCO_2$, which is higher than the target of 240 $MtCO_2$. It is possible that the CO_2 intensity could become higher than the planned 2030 electricity mix.

Impact of plans for the new coal-fired power plants on long-term targets (2050 targets)

To achieve an 80% reduction of GHG emissions by 2050, as stipulated in the Fourth Basic Environment Plan, GHG emissions in 2050 must be reduced to 247 – 270 $MtCO_2$. However, it will be difficult for Japan to achieve the 2050 targets, as CO_2 emissions from the new coal-fired power plants in 2050 are estimated to be 98 $MtCO_2$ (approximately 36-40% of the GHG emissions cap in the 2050 targets) and emissions from all coal-fired power plants, including existing facilities, are estimated to be 110 $MtCO_2$ (approximately 41-45% of the GHG emissions cap for the 2050 targets). In addition, the results of calculations on the amount of power generated from the implementation of plans for the new coal-fired power plants clearly indicate that that the amount of power generated as estimated in the 2℃ target scenarios deviates widely. This produces a “lock-in effect” where CO_2 emissions remain high for many years.

Achieving mid- and long-term targets

In order to reduce the intensity in the electricity sector to achieve Japan’s mid- and long-term targets and the 2 degree target scenarios, the revisions of plans for the new coal-fired power plants must be sincerely discussed from the outset with regard to renewables, nuclear power generation as well as CO_2 capture and storage (CCS). If the carbon price exceeds JPY 6,000/tCO_2, the economic advantage of coal-fired power generation can fall in comparison with natural gas-fired power generation and major renewable energies, such as wind and solar power. As actions related to carbon pricing are being promoted through the introduction of carbon taxes and emissions trading by international society, Japan also needs to seriously discuss a framework for the entire power sector.

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1 Background and Objectives

On 17 July 2015, the Japanese government has also submitted its INDC, which aims to reduce the county's greenhouse gas (GHG) emissions by 26% from 2013 levels by 2030 (25.4% reduction from 2005 levels). Japan's INDC is calculated based on a recently-developed electricity mix plan for 2030 (METI, 2015b), which aims for the following mix: 20 – 22% nuclear, 26% coal, 3% oil, 27% natural gas, and 22 – 24% renewables. Although a balanced electricity mix is crucial for Japan to strengthen its energy security, concerns have been raised that the relatively high coal-fired power share target may hinder Japan's long-term efforts on the deep reduction of GHG emissions. Since the economic lifetime of coal-fired power plants is typically 40 years, the consistency with Japan's mid- and long-term climate change policies must be examined when planning to retrofit facilities for coal-fired power generation.

In parallel with the development of the INDC and the 2030 electricity mix plan, a large number of plans for the constructions of new coal-fired power plants have been developed by electric utilities following the Fukushima nuclear disaster of 2011. As a result of the impact from shuttering the country's nuclear power plants in recent years, Japan is also planning constructions or retrofit to its coal-fired power plants with a total capacity of 18 GW[1] (referred to as "the new coal-fired power plants" below) as of 9 November 2015, which is more than 40% of the currently existing coal power capacity. To date, it has not been examined whether these new coal-fired power plant constructions planned by electric utilities are consistent with the 2030 electricity mix plan.

Against the aforementioned backdrop, this paper first assesse the Japan's expected electricity CO_2 intensity in 2030 under the current policy plans in consistent with the 2 ℃ pathways by comparing it with the range of values for scenarios[2] that keep the average global temperature rise to below 2℃ from pre-industrial levels. The results are also compared with the expected electricity CO_2 intensity values estimated for the U.S. and the EU. The paper also quantifies the extent to which emissions from the new constructions to thermal power plants can remain at high levels, in other words, the "lock-in effect." Lastly, the paper calculates the economic impact on coal-fired plants when carbon pricing schemes such as carbon taxes and emissions trading are implemented.

Section 2 includes a summary of the positioning of CO_2 emissions in the energy sector of each country. Section 3 presents the methods and data used for the analysis. Section 4 presents the projections on the CO_2 intensity in the power sector by calculating the estimated CO_2

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[1] Calculated by IGES based on MOEJ's press release and Kiko Network (2015a)

[2] Here, a scenario to control the atmospheric concentration of greenhouse gases in 2100 to below 450 ppm CO_2 -equivalent is used.

intensity and total CO_2 emissions in the domestic power sector in 2030 based on the proposed electricity mix for 2030, and offers a comparison of policy targets in the U.S. and the EU. The section also includes a comparison of the CO_2 intensity and total CO_2 emissions in the domestic power sector under the 2℃ target scenarios produced by prominent research institutes and think tanks. Section 5 includes a discussion on lock-in effects for CO_2 emissions from the new coal-fired power plants, compared with Japan's mid- and long-term targets. Section 6 presents an analysis of the economic risks from updating coal-fired power plants in terms of offset and carbon pricing. Finally, conclusions and recommendations are drawn in Section 7.

2 CO_2 Emissions from the Power Sector in Japan, the U.S. and the EU: Current status and future targets

This section provides an overview of current CO_2 emissions and the future CO_2 reduction targets in the power sector in three countries, i.e. Japan, the U.S. and the EU.

2.1 CO_2 emissions in Japan, the U.S. and the EU

Figure 1 presents CO_2 emissions from the power sector in 2012 by fuel in the three countries. Total GHG emissions in Japan in 2012, following the Fukushima nuclear accident and the subsequent shut down of nuclear reactors nationwide, were 1,343 $MtCO_2e$[3], of which CO_2 emissions related to energy use were 1,222 $MtCO_2$ (NIES, 2014). CO_2 emissions from the power sector autoproducers (but excluding waste power generation) were 562 $MtCO_2$, which corresponds to 42% of all GHG emissions in Japan. CO_2 emissions from coal-fired power plants is 276 $MtCO_2$, which is equivalent to 49% of GHG emissions in the power sector (IEA, 2014d), and at 21%, accounts for a large proportion of total GHG emissions in Japan.

GHG emissions in the U.S. were 6,487 $MtCO_2e$[4], of which energy-related CO_2 emissions related to energy use were 5,203 $MtCO_2$ (EPA, 2014b). CO_2 emissions from the power sector, autoproducers (but excluding waste power generation) were 2,064 $MtCO_2$, which corresponds to 32% of total GHG emissions in the U.S. CO_2 emissions from coal-fired power plants are 1,507 $MtCO_2$, which is equivalent to 73% of GHG emissions in the power sector, account for 23% of all GHG emissions in the U.S.

[3] Excluding emissions and removals from land use, land use change and forestry (LULUCF)

[4] Excluding emissions and removals from LULUCF

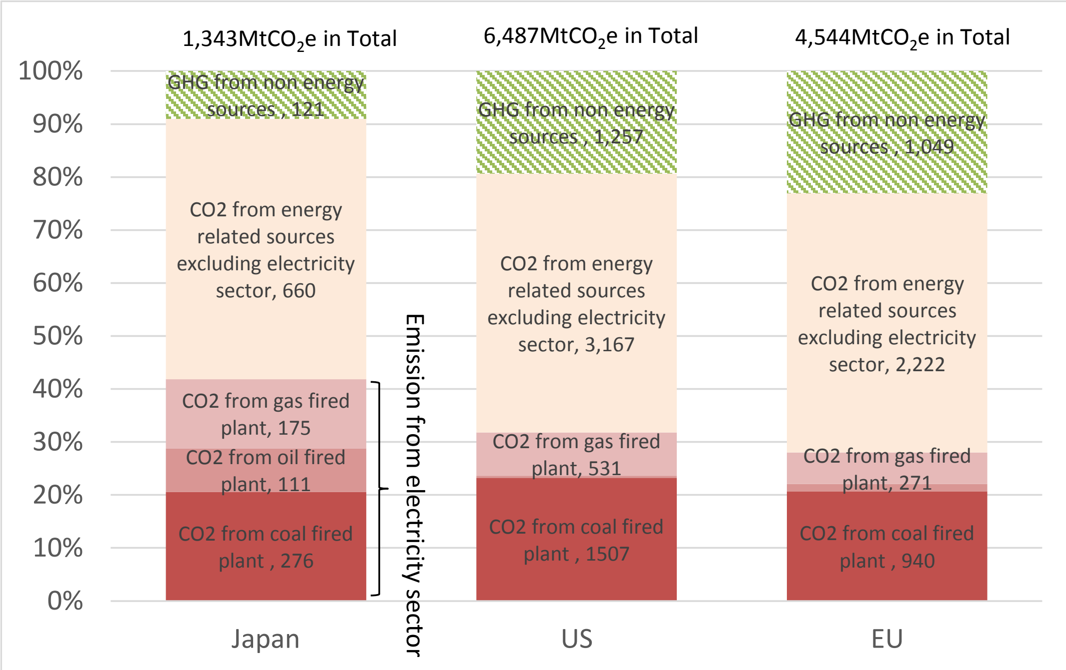


Figure 1. CO_2 **emissions in the power sector by fuel in Japan, the United States, and the EU (2012)**

Source: GHG emissions by sector created by the authors based on NIES (2014), EPA (2014), and EEA (2014). CO_2 emissions in the power sector created by the authors based on IEA (2014d).

GHG emissions in the EU (European Union) were 4,544 $MtCO_2e$[5] (excluding emissions and removals from LULUCF), of which energy-related CO_2 emissions related to energy use were 3,495 $MtCO_2e$ (EEA, 2014). CO_2 emissions from the power sector, including autoproducers (excluding waste power generation), were 1,273 $MtCO_2$, which is equivalent to 28% of all GHG emissions in the EU. CO_2 emissions from coal-fired power plants are 940 $MtCO_2$ and are equivalent to 74% of GHG emissions in the power sector. This is equivalent to 21% of GHG emissions in the entire EU. The ratio of GHG emissions other than energy related CO_2 is the highest, with methane from agriculture and animal husbandry making up the main sources of emissions.

As described above, the share of CO_2 emissions in the power sector in Japan is high in comparison with other countries, which indicates the increasing importance of improving the intensity in the power sector.

[5] Excluding emissions and removals from LULUCF

2.2 Future GHG mitigation targets and the related policies for the power sector

Data were compiled on current GHG emission reduction policies by Japan, the U.S., and the EU, especially with regard to the power sector. Table 1 features a summary of the policies in each country.

Table 1. List of policies that have been implemented, planned or proposed by country

	Mid-term reduction targets (cross-cutting measures)	Major measures in the power sector
Japan	26% reduction by 2030 from 2013 levels	● Base load power supply of 60% (nuclear power: 20%-22%, coal-fired power: 26%, renewables, including hydropower and geothermal power: 22%-24%, LNG: 27%, oil: 3%)
United States	26% to 28% reduction of GHG emissions by 2025 from 2005 levels	● Introduction of Clean Power Plan (30% reduction of emissions from power sector by 2030 compared to 2005 levels) and carbon pollution standard ● Continued support for renewables and nuclear power plants
Europe	40% reduction of GHG emissions by 2030 from 1990 levels	● 27% share of renewables in final energy consumption by 2030 (Increase from 21% (current level) to 45% in the power sector).

Source: Created by the authors based on IEA (2014d), METI (2015b), EPA (2014b), EU (2014).

Estimations for the CO_2 intensity in the power sector have been carried out and compiled in Figure2. Since the Great East Japan Earthquake, Japan has suspended the operation of nuclear power plants, which resulted in the increase of thermal power generation that accounts for 85% of all power generation in 2012. The share of renewables in the total amount of power generated was only 12%, including waste power generation. As a result, the intensity in 2010, which was 0.41 tCO_2/MWh, rose to 0.55 tCO_2/MWh in 2012, as seen in Figure 2. The breakdown of thermal power plants, in particular, illustrates a unique situation in comparison with other countries, due to the large difference between peak demand and the lowest demand on one day[6], and the frequent use of oil-fired power generation at 17.5%. In Japan's INDC, which indicates a 26% reduction by 2030 from 2013 levels, if the ratio of coal-fired power generation is set at 26%, Japan's intensity in 2030 will be calculated as 0.36 tCO_2/MWh.

The intensity in the electricity sector in the U.S. was 0.53 tCO_2/MWh in 2010. In 2012, the intensity dropped to 0.49 tCO_2/MWh, which was lower than that in Japan, due to the impacts from the increase in the number of natural gas-fired power plants in recent years. This translates as a reduction of 30% in emissions from the power sector by 2030 from 2005 levels. It is expected that the intensity will eventually reach 0.34 – 0.38 tCO_2/MWh since the amount

[6] Refer to Kuramochi & Asuka (2012)

of power generated in 2030 is estimated to be 4,450 – 5,003 TWh (EIA, 2014b) according to the degree of economic growth.

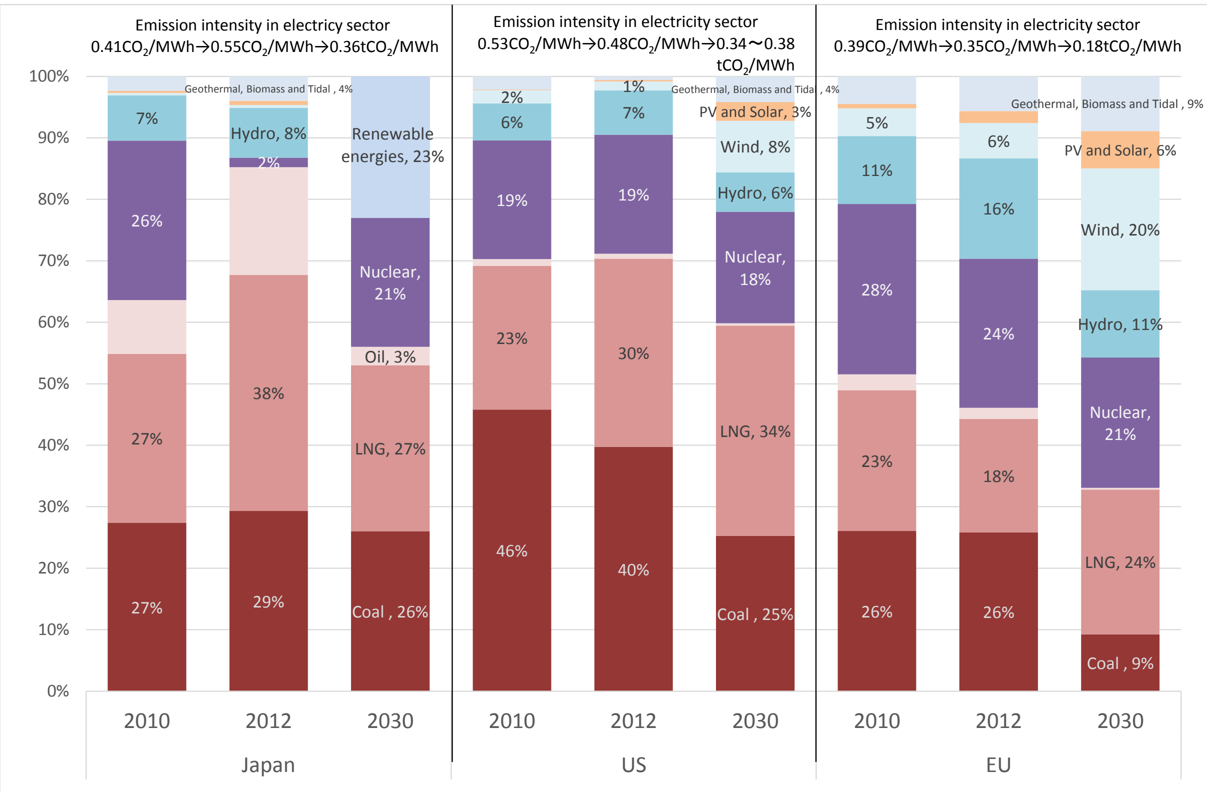


Figure 2. Comparison of current electricity mix by country in 2010, 2012, and 2030
Source: Created by the authors based on IEA (2014d), METI (2015b), EPA (2014b), EU (2014).

In addition to the use of nuclear power generation, the EU is moving towards a share of about 29% for renewables, including waste-to-energy power generation, with an emissions factor of 0.37 tCO_2/MWh as of 2012, and is currently promoting the development of low-carbon power. The EU submitted its mid-term reduction targets to the UNFCCC Secretariat on 6 March 2015, in which it announced that it would seek a 30% reduction in GHG emissions by 2030 from 1990 levels. In order to achieve this target, the European Parliament has set a target of a 27% share of renewables in final energy consumption, and a renewable energy target of 45% in the power sector (EC, 2014). This figure, which can be calculated as 0.18 tCO_2/MWh, surpasses the intensity estimated at 0.23 tCO_2/MWh in the New Policies Scenario of WEO 2014.

As described above, it is possible that, even with the restart of nuclear energy plants in the country, the intensity in the power sector in Japan will be similar to that of the U.S. or higher than the EU. Both the U.S. and the EU have reduced the utilization rate of coal-fired power generation in the power sector. However, the utilization rate of coal-fired power generation in Japan has consistently remained between 25% and 30% since 2010, which is why the intensity has not fallen significantly. Since this value does not take into account the impact of the new coal-fired power plants, as discussed in Section 5, and the increase in the amount of power generated from coal-fired power plants, as estimated in the 2030 electricity mix, the intensity in Japan could end up higher than 0.36 tCO_2/MWh. It should be noted that consistency with the 2℃ target scenarios is examined in Section 4.2 below.

3 Method and Data for Analysis

First, a comparison and evaluation of the current state and predictive values for the intensity in the power sector are analysed in Section 4. Analysis of the lock-in effects of coal-fired power plants are evaluated in Section 5. Section 6 examines the effects of carbon pricing for the new coal-fired power plants.

3.1 Summary of scenarios used as reference in each analysis

This paper cited the estimations of power generation and CO_2 emissions from coal-fired power generation in Japan's 2030 scenario and 2℃ target scenarios that have been published by various research institutes to evaluate the intensity in the power sector and lock-in effects from the new coal-fired power plants, as well as calculate carbon offsets for CO_2 emissions from coal-fired power plants. These scenarios are compiled in Table 2.

The New Policy Scenario in the World Energy Outlook (WEO) 2014 of the International Energy Agency (IEA) illustrates the emission factors for the intensity in the power sector in Japan in 2030.[7] According to Japan's long-term energy outlook (METI, 2015b), total power generation was set to 1,065 TWh, with an electricity mix of 21% nuclear, 26% coal, 3% oil, 27% natural gas, and 23% renewables. Emission factors were calculated for all new and existing facilities.

Based on data on the start of operations mentioned in the Kiko Network (2015a) for the amount of power generated by existing power plants for all types of thermal power, the ratios of existing thermal power plants that will have been in operation for over 40 years were estimated to be 11% in 2020, 28% in 2030, 68% in 2040, and 96% in 2050, respectively.[8] According to the ANRE (2012), the ratio of natural gas-fired power generation facilities in operation over 40 years was 17% in 2012 and will be 37% in 2020, 52% in 2030, and 84% in 2040, respectively. Thermal power plants that exceed their service life are not used, and it is presumed that facilities must be retrofitted or discontinued. For 2030 electricity mix, the amount of power

[7] CO_2 emissions scenario in cases where energy-related policies and numerical targets that have been proposed to mid-2014 have been executed.

[8] According to the Agency for Natural Resources and Energy (2012), the ratio of coal-fired power plants in operation for more than 40 years will remain consistent at 12% in 2020, 32% in 2030, and 77% in 2040.

generated by the new constructions or retrofits to thermal power plants was calculated by subtracting the amount of power generated by existing facilities from the amount of power generated. The estimated amount of power generated by power plants in operation under 40 years in 2030 was calculated based on IEA(2014a), Kiko Network (2015a), and ANRE (2012).

Table 2. List of scenarios from each organization used to evaluate results of analyses

Document name	Evaluation targets	Overview of scenario
MOEJ (2012a): Report on measures and policies from 2013 and beyond	2030 targets	Presents multiple measures and policies in which the power generation ratio is 0% to 35% using nuclear power based on a request from the Energy and Environment Council.
METI (2013): FY 2012 Study on Overall Strategy for Energy and Environment		Presents multiple measures and policies in which the power generation ratio is 0% to 35% using nuclear power under the Study on Overall Strategy for Energy and Environment.
World Energy Outlook(WEO) 2014: 450 Scenario(IEA, 2014d):	2030 targets and 2℃ target scenarios	Contains information on energy demand, production, trade, investment, and CO_2 emissions by country, region, fuel type, and sector for energy trends to 2040, based on energy data from IEA. This paper uses New Policy Scenarios and the 450 scenario.[9]
Deep Decarbonization Pathways Project (SDSN・IDDRI, 2014a, 2014b)	2℃ target scenarios	Illustrates the pathways to decarbonization of 15 major CO_2 emitter countries to achieve the 2℃ target scenarios. This scenario aims at a 1.6 tonne reduction of energy related CO_2 emissions related per capita by 2050.
LIMITS Project (Comparative study of seven integrated assessment models)		Comparative study based on models AIM-Enduse, GCAM, IMAGE, MESSAGE, REMIND, TIAM-ECN, and WITCH. Data on primary energy supply and energy demand has been recorded. This paper uses the 450 ppm Scenario.

3.2 Calculation and evaluation of the CO_2 intensity in the power sector for each country

Emission factors for existing coal-fired power plants and natural gas-fired power plants were calculated using the amount of power generated in each power sector and CO_2 emissions in 2012, based on IEA (2014d). Emission factors for additional coal-fired power plants, natural gas-fired power plants, and oil-fired power plants were calculated using plant load factors[10] offered by the METI (2015b) (coal: 80%, LNG: 80%). Thermal efficiency was calculated using values for the latest technologies that are currently being used commercially as mentioned by MOEJ (2014); the carbon intensity by fossil fuel source was calculated based on values

[9] Scenario to achieve 2℃ targets by introducing global carbon pricing in order to stabilize CO_2 concentrations in the atmosphere at 450 ppm by 2100.

[10] The Principles for IEA Action on Coal adopted in the 1979 Communique of the 3rd IEA Governing Board Meeting at the Ministerial Level precludes the construction of new or replacement base load oil-fired capacity facilities. Therefore, the utilization rate of oil-fired power generation was estimated as the utilization rate needed to meet the estimated amount of oil-fired power generation in the proposed 2030 electricity mix.

described by IEEJ (2014a). Finally, emission factors for all sectors were determined by calculating the CO_2 emissions in each sector using emission factors and the amount of power generated by existing and retrofitted facilities in 2030. These results are summarized in Table 3.

Table 3. Emission factor of thermal power plants in Japan in 2030

	Thermal efficiency (high heating value basis)	Emission factor (tCO_2/MWh)	Estimated amount of power generated in 2030 (TWh)
Average amount of all coal-fired power generation as of 2030	**-**	**0.88**	**277**
Existing coal-fired power generation	36%	0.91	212
New coal-fired power plants	42%	0.78	65
Average amount of natural gas-fired power generation as of 2030	**-**	**0.41**	**288**
Existing natural gas-fired power generation	40%	0.44	206
New natural gas-fired power plants	52%	0.34	81
Average oil-fired power generation as of 2030	39%	**0.66**	**32**

Source: Created by the authors based on Kiko Network (2015b), ANRE (2012), METI (2015 a and b), (MOEJ, 2014), IEA (2014d), IEEJ (2014a),

On 12 November 2014, the U.S. announced a reduction of 26% to 28% for greenhouse gas (GHG) emissions by 2025 from 2005 levels at a bilateral meeting between the U.S. and China. The main policy tool to achieve this target is the Clean Power Plan[11] that was formulated by the Environmental Protection Agency (EPA) based on The President's Climate Action Plan, a policy position of U.S. President Barak Obama, which includes a 32% reduction of emissions from the power sector by 2030 from 2005 levels. The intensity in the U.S. power sector was calculated based on data from the U.S. Energy Information Administration (EIA). To calculate U.S.'s intensity in power sector, the 70% of CO_2 emissions in 2005 was divided by the EIA's estimation for electricity supply in 2030. In fact EIA (2014b) have low, standard, and high economic growth scenarios for estimation of electricity supply. Therefore, this paper also shows three intensity scenarios.

For the EU's intensity in the power sector, this paper referred the electricity supply and CO_2 emission for 2030 in New Policy Scenario in the WEO 2014. Also, it refers the electricity supply and CO_2 emission for 2040 in New Policy Scenario, which is corresponded with the statement

[11] For details on the Clean Power Plan, refer to Kuriyama and Yoshino (2014).

in EC (2014) as " the share of renewable energy in the electricity sector would increase from 21% today to at least 45% in 2030".

In order to evaluate the estimated intensity in the power sector, the predicted values for the intensities in the power sector in 2030 for Japan, U.S. and EU were compared with each 2℃ target scenario. The estimated intensity was also calculated using the 2℃ target scenarios of the EU LIMITS Project (450 Benchmark scenario), WEO 2014, and the Deep Decarbonization Pathways Project (SDSN/IDDRI, 2014a, 2014b). An overview of each scenario is described in Table 2.

3.3 Lock-in effect from the new coal-fired power plants (impact on mid- and long-term targets)

In order to discuss the lock-in effects from the new coal-fired power plants as discussed in Section 5, CO_2 emissions and power generation from both existing coal-fired power plants and plants with increased capacity were calculated. The amount of power generated and emission factors from existing coal-fired power plants are the same as those listed Table 3 in Section 3.2. Data for information on the capacity of the new coal-fired power plants were originally corrected based on MOEJ's press release and Kiko Network (2015a). The values in Table 3 were used for emission factors of thermal power plants.

To assess the impact of newly constructed coal-fired power plants on the proposed 2030 electricity mix and 2℃ target scenarios, CO_2 emissions from coal-fired power plants that are included in the proposed 2030 electricity mix were first compared with GHG emissions for when an "80% reduction in greenhouse gases will be achieved by 2050" (hereinafter referred to as the 2050 targets), as mentioned in the 4th Basic Environment Plan (Cabinet Decision on 27 April 2012).

Next, the amount of power generated[12] from coal-fired power plants stipulated in Japan's intended nationally determined contributions and the estimated amount of power generated using the LIMITS project, WEO 2014, and the Deep Decarbonization Pathways Project (DDPP) scenario were compared, as well as scenarios for the formulation of mid-term targets for 2030 by the government, including MOEJ (2012a) and METI (2013) The reason for conducting a comparison using the amount of electricity generation is that intensity in the power sector varies widely in the scenarios of each organization, and it was difficult to conduct a comparison using CO_2 emissions. An overview of each scenario is outlined in Table 2.

[12]The reason for a comparison using the amount of power generated is to improve the relevance of lock-in effects due to the differences in emission factors from individual power plants.

3.4 Economic disadvantage of coal-fired power generation by carbon pricing

With regard to a calculation on the impacts of carbon tax for CO_2 emissions from the new coal-fired power plants as described in Section 5. In order to evaluate the economic advantage of coal-fired power generation when domestic carbon prices are set, the costs of CO_2 measures that were included in the power generation cost per 1 kWh were calculated for each case. In order to compare power generation costs excluding policy expenses, the values obtained from the data included in (METI, 2015a) were used for the cost of power generation per 1 kWh.

4 Country Comparison and Evaluation of the CO_2 Intensity in the Power Sector

4.1 Evaluation of consistency with long-term targets for CO_2 intensity by country

The predicted value of the intensity in the power sector in each country, as calculated in Section 4.1, is within the range of the energy pathway comparison of the intensity in the 2℃ target scenarios of each organization (pink colour section in Figure 3: The intensity in the 2℃ target scenarios based on an assumption that CCS has been introduced in some thermal power plants; orange colour section in Figure 3: The intensity in the 2℃ target scenarios based on the assumption that CCS has not been introduced in thermal power plants). A summary of the scenarios of each organization are described in Table 2. .

The intensity in Japan in 2030 will be 0.36 tCO_2/MWh, as per calculations based on the methods introduced in Section 2 for the latest global warming mitigation measures in Japan. This value is indicated by the red line in Figure 3. As indicated by the blue line in Figure 3, the intensity in the power sector as calculated by WEO 2014 will be 0.33 tCO_2/MWh based on a 3.8% reduction target by 2020 from 2005 levels, as announced by the Japanese government in 2013. Therefore, it is expected that the intensity under the current INDC will be lower than the former emission reduction target, i.e. a 3.8% reduction by 2020 from 2005 levels. In addition, the intensity in Japan does not meet the intensity that can be calculated from each 2℃ target scenario. The major reason for this is the use of coal-fired power generation, which exceeds the estimates in each scenario.

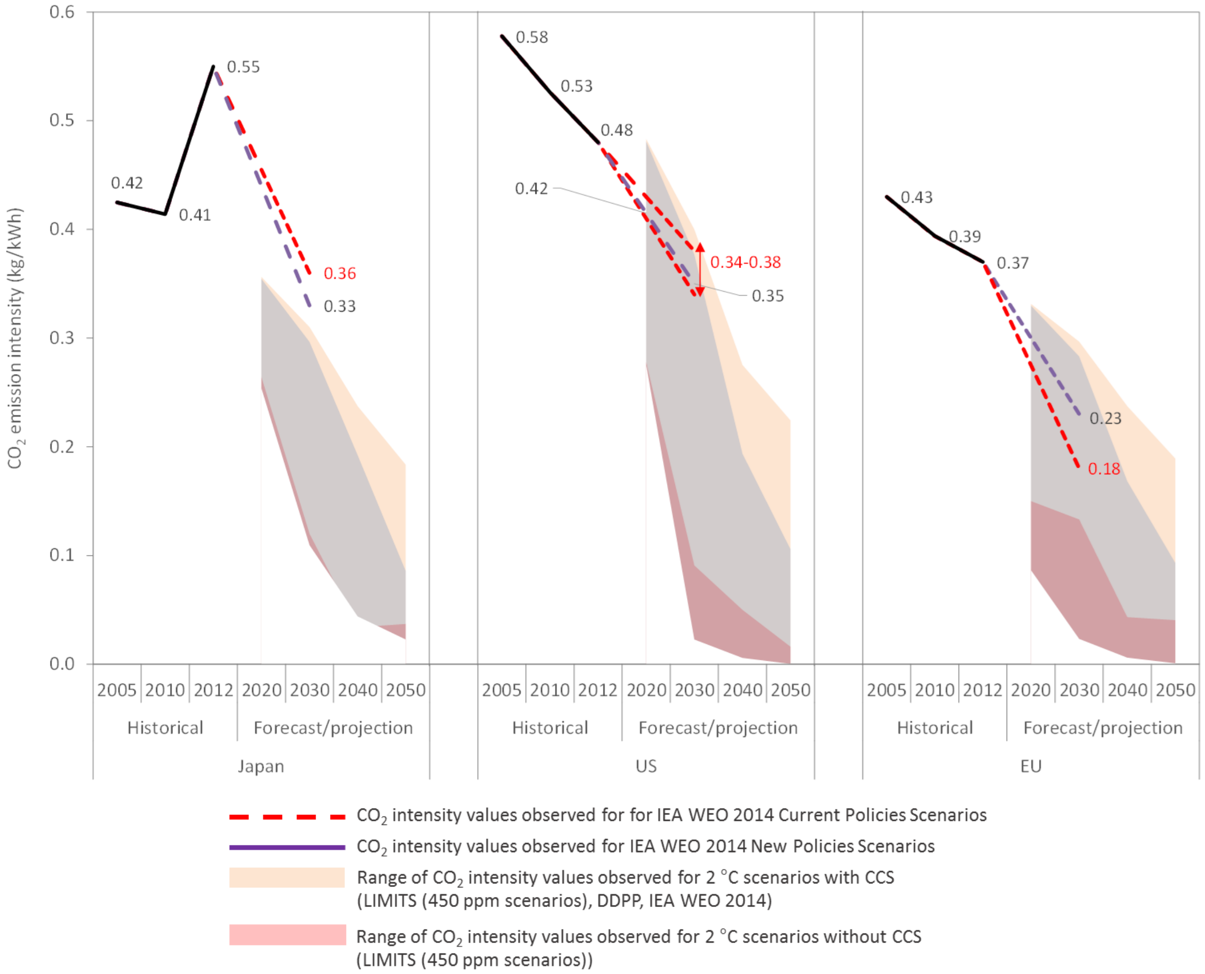


Figure 3. Forecasts for the intensity in electric sector rates for each country in 2030

Source: Created by the authors based on IEA (2014, 2014b and 2014c), EC (2014), EIA (2014b), MOEJ (2012), IIASA (2014),(METI, 2013).

Although no particular electricity mix is specified, the U.S. does indicate clear targets of a 30% reduction in emissions from the power sector by 2030 from 2005 levels. The intensity in the power sector calculated using (EIA, 2014a, b) is 0.34 – 0.38 tCO_2/MWh, which is roughly consistent with the figure of 0.35 tCO_2/MWh as calculated in the New Policies Scenario of WEO 2014. This figure is also within the range of the 2℃ target scenarios of each research institute.

With the EU setting a renewable energy target of 45% in the power sector by 2030 (EC, 2014), the intensity in the power sector will drop to 0.18 tCO_2/MWh, and as described above, this will be a scenario in which the target intensity will be achieved well ahead of the intensity target for 2040, as indicated in the New Policies Scenario of WEO 2014. In addition to this new emissions reduction, the EU will be able to meet the intensity target in the 2℃ target scenarios of each research institute.

As seen in Section 4.1, the mid-term targets of Japan will not only result in an intensity in the power sector that is higher than that of the U.S. or the EU; these targets are also not consistent with the 2℃ target scenarios, and it is clear that its legitimacy in the international community is low.

5 Assessment of Impacts on Japan's Mid- and Long-Term Targets with the Increase of Coal-Fired Power Plants

The current installed capacity of coal-fired power plants in Japan owned by wholesale electric utilities, general electric utilities, specified electric utilities, and power producers and suppliers is 35.94 GW (IEA, 2014a). In addition, there is a 6.1 GW of private coal-fired power plants (Kiko Network 2015b) that the total coal-fired power capacity in Japan amounts up to 42 GW. As a result, coal-fired power plant accounts for 21% of GHG emissions in Japan and 49% of CO_2 emissions from the power sector as of 2012. As aforementioned, there are the plans for the new coal-fired power plants with a capacity of 18 GW. In this section, it assess an impact on Japan's mid- and long-term emission reduction target by existing and new coal-fired power plants.

5.1 Changes in CO_2 emissions from coal-fired power plants and evaluation of compatibility with mid- and long-term reduction targets

Figure 4 shows the CO_2 emissions from coal-fired power plants considering the expected lifetime and the installed capacity of new coal-fired power plants that have been planned as of March 2015 based on the methods described in Section 3. It also shows the CO_2 emission from coal-fired plant under the 2030 target and total GHG emissions in the 2050 target.

The double blue line in the figure above represents CO_2 emissions from coal-fired power plants that have been in operation under 40 years (hereinafter referred to as the scenario on the successive phase out of coal-fired power). In this scenario, CO_2 emissions from coal-fired power plants will be 193 $MtCO_2$ by 2030, 86 $MtCO_2$by 2040, and 12 $MtCO_2$by 2050. The installed capacity in this scenario was 39 GW in 2012, and is estimated to be 37 GW by 2020, 30 GW by 2030, 13 GW by 2040, and 2 GW by 2050, respectively.

The double red line represents the CO_2 emissions from the operation of coal-fired power plants under 40 years, as well as coal-fired power plants that are currently planned (hereinafter referred to as the scenario on newly constructed coal-fired power plants). With the operation of all coal-fired power plants that have increased capacity, an additional 126 TWh will be added to the current amount of power generated by coal-fired power plants, and an additional 98 $MtCO_2$ will be added to CO_2 emissions. This corresponds to about 9% of total GHG emissions in 1990.

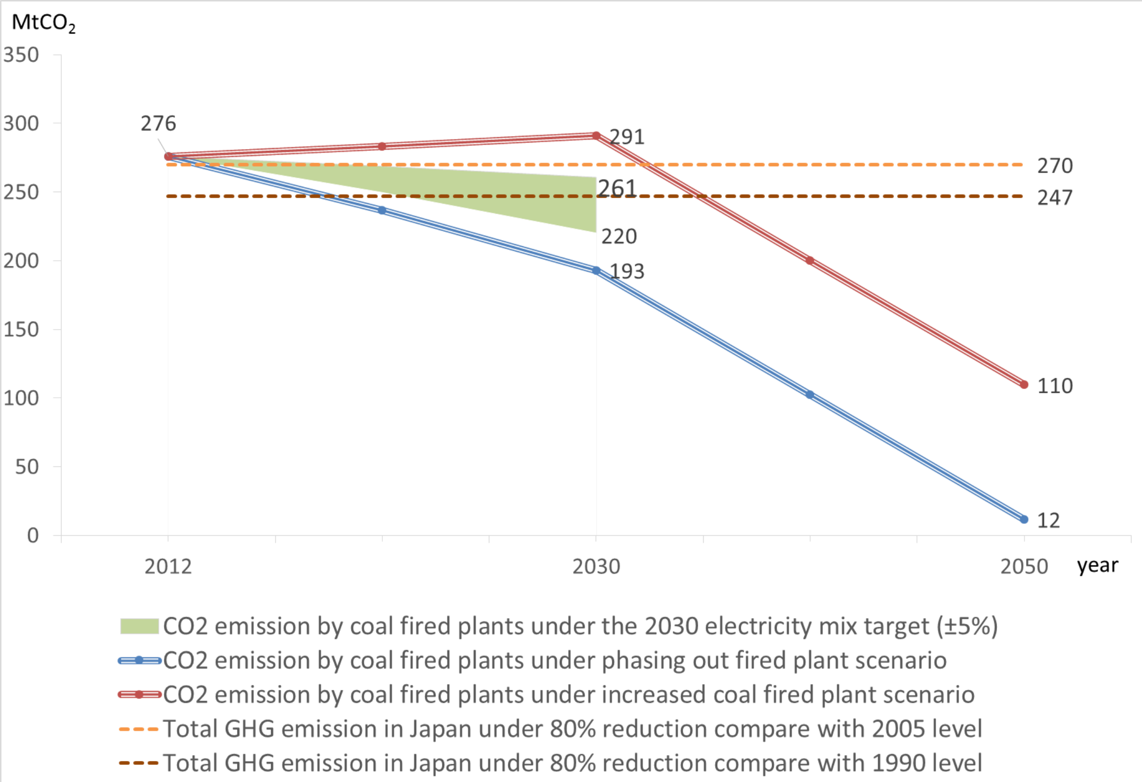


Figure 4. CO_2 emissions when planned coal-fired power plants are in operation

Source: Kiko Network (2015a), IEA (2014a), MOEJ (2012c), MOEJ (2012b), METI (2015b)

As described above, the share of coal-fired power generation in the proposed 2030 electricity mix included in Japan's INDC, which is also Japan's mid-term reduction target, is approximately 26% of the total amount of power generated. Power generation as of 2030 is estimated to be about 1,065 TWh under the proposed 2030 electricity mix. In multiple scenarios by MOEJ (2012a) and METI (2013), this figure is 950 – 1,150 TWh. Therefore, the range of the total amount of power generated is between 247 – 299 TWh when multiplied by 0.26, which is the ratio of the amount of power generated by coal-fired power plants as defined in the INDC. As illustrated in Table 3, the figure of 212 TWh for existing thermal power generation in 2030 is multiplied by 0.91 tCO_2/MWh as the emissions factor, and the remaining amount of power generated is multiplied by 0.78 tCO_2/MWh, which is emissions factor of the new coal-fired power plants to calculate a total of 220 to 261 $MtCO_2$. As a result, it is clear that the amount of power generated by coal-fired power plants in the proposed 2030 electricity mix is higher than the scenario on the successive phase out of coal-fired power, but lower than the amount of coal-fired power generation in the scenario on newly constructed coal-fired power plants. Specifically, the total amount of power supplied in 2030 under the scenario on the newly constructed coal-fired power plants is 338 TWh, and CO_2 emissions total 291 $MtCO_2$. Therefore, there is a possibility that if all the new coal-fired power plants with a capacity of 18 GW are implemented, it will no longer be consistent with the proposed 2030 electricity mix, and it will be difficult to develop another plant to build coal-fired power plants in terms of achieving the reduction targets in Japan's INDC.

To achieve the 2050 targets in the Fourth Basic Environmental Plan, there is a need to reduce 2050 emissions to between 247 $MtCO_2$ (1990 base year) to 270 $MtCO_2$ (2005 base year), shown as yellow and brown lines, to determine consistency with Japan's long-term reduction targets. If all the new coal-fired power plants are implemented, the amount of power generated from these power plants will account for about 41% to 45% of all CO_2 emissions in Japan. Here, the lock-in effect of the new coal-fired power plants figures prominently.

5.2 Comparison with the amount of power generated by coal-fired power generation in scenarios by research institutes

In this section, the impacts of the new coal-fired power plants on Japan's INDC and 2℃ target scenarios were examined with the scenarios by several research institutes. Figure 5 shows a comparison of the amount of power generated in 2030 in various literature that analyses the mid- and long-term targets of Japan, in addition to the scenario on the successive phase out of coal-fired power and the scenario on the new coal-fired power plants. The total amount of power generated in 2030 under the scenario on the new coal-fired power plants is 338 TWh. The total amount of power generated in the scenario on the successive phase out of coal-fired power plants is 212 TWh.

The range shown in green is the range for the coal-fired power generation in cases where the total amount of power generated is 950 – 1,150 TWh respectively in the INDC, namely, a scenario in which the share of coal-fired power generation is 26% of the amount of power supplied.

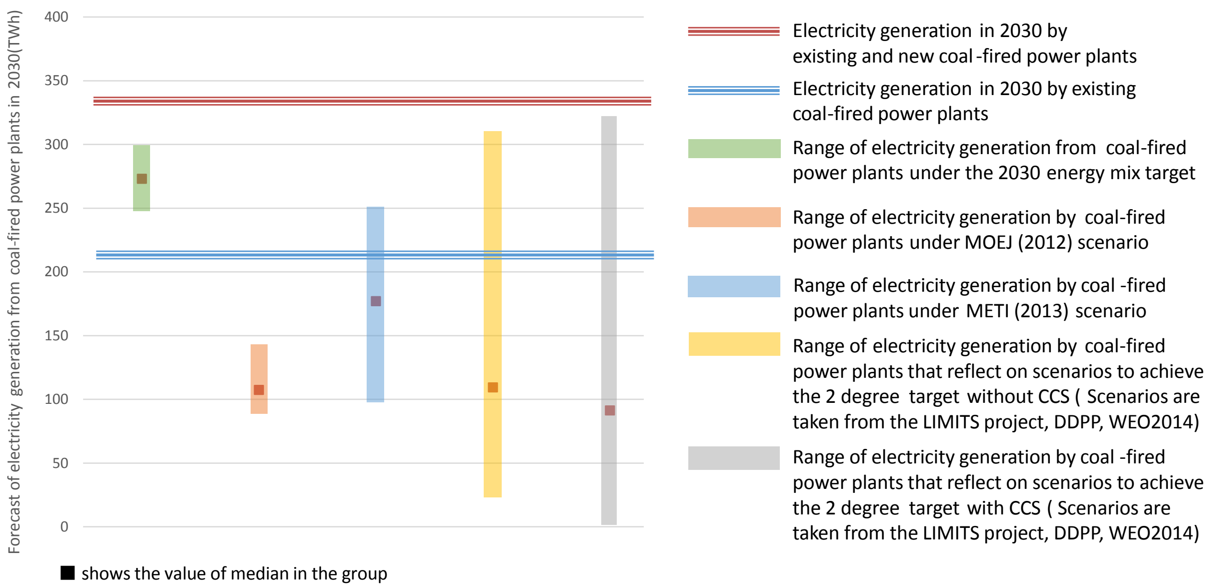


Figure 5. Forecasts on power supply from coal-fired power plants as of 2030 in each scenario

Source: Created by the authors based on Kiko Network (2015a), MOEJ (2012 a and b), Government of Japan (2015), METI (2013), IIASA (2014), SDSN & IDDRI (2014a).

The range shown in orange indicates for coal-fired power generation under the scenario of MOEJ (2012a). The range shown in blue indicates the breadth of the scenario of power generated by coal-fired power plants in each draft reduction policy contained in METI (2013). The range shown in yellow indicates the breadth of the scenario of power generated by coal-fired power plants in cases where CCS technologies are not used in the 2℃ target scenarios of WEO 2014, DDPP, and the LIMITS project. The grey sections indicate the breadth of the scenario of power generated by coal-fired power plants in cases where CSS technologies are used in the aforementioned 2℃ target scenarios.

Although the scenario in which coal-fired power generation is successively phased out does not reach the range for scenarios specified by MOEJ, it does satisfy the most part of the range for 2℃ target scenarios. In addition, the levels in scenarios in which coal-fired power generation is successively phased out are lower than the amount of power generated by coal-fired power plants that is included in the proposed 2030 electricity mix. It is clear that this is a scenario that is consistent with the achievement of reduction targets in the INDC.

Alternatively, it is likely that the amount of power generated by coal-fired power plants in the scenario on the new coal-fired power plants will exceed the amount of power generated by coal-fired power plants in the proposed 2030 electricity mix. This figure will also far exceed the range for scenarios to 2030 that have been estimated by MOEJ (2012a) and METI (2013).

Furthermore, the range is significantly higher than the median value of the 2℃ target scenarios, and is also higher than the maximum value. Therefore, if all the new coal-fired power plants are implemented, the range of estimated electricity generation will exceed the scenarios to achieve the INDC. In addition, when taking the 40-year operation life of coal-fired power plants into account, a lock-in effect will be produced in which the amount of power from coal-fired power generation remains high even after 2030, and it is likely that this will significantly impact the achievement of the 2050 targets.

6 Examination of economic disadvantages of coal-fired power plants by implementation of carbon pricing

As countries around the world look towards the creation of low-carbon societies, movements to introduce carbon pricing, such as emissions trading, environmental taxes, and voluntary emissions reduction targets, have become widespread. Thus, this chapter examines an economic impact on generate electricity generation costs by implementation of carbon pricing.

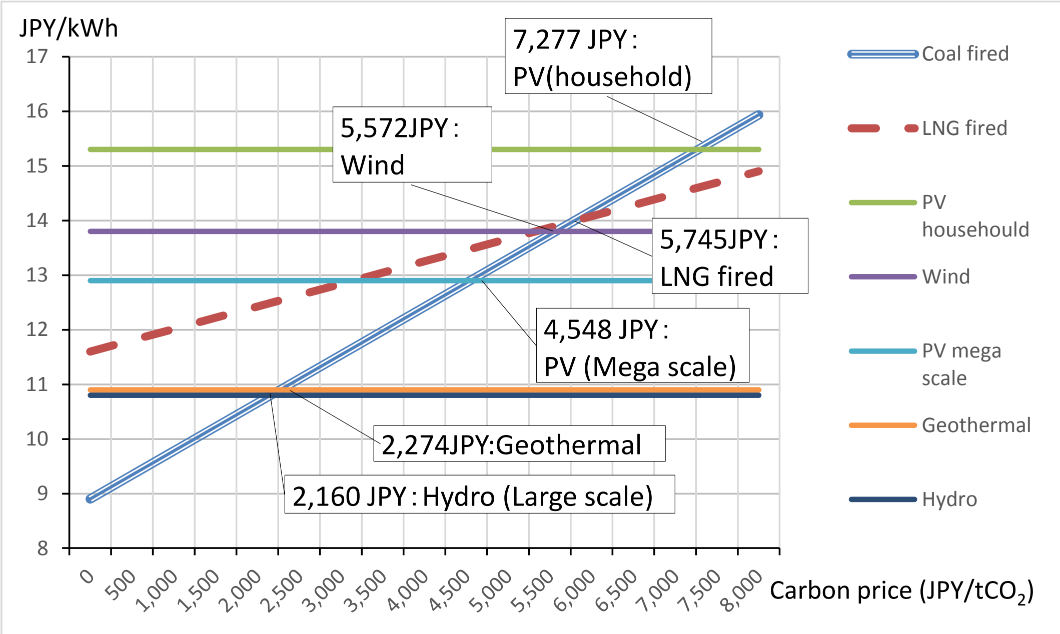
According to the METI (2015a), the power generation cost per 1 kWh, excluding policy costs for general hydropower, geothermal power, large-scale (mega) solar power, onshore wind power, and solar power for households, are estimated to be JPY 10.8/kWh (C_{hydro}), JPY 10.9/kWh ($C_{geothermal}$), JPY 12.9/kWh ($C_{largePV}$), JPY 13.8/kWh (C_{wind}), and JPY 15.3/kWh ($C_{smallPV}$), respectively.

The power generation cost per 1 kWh, excluding policy expenses and costs for CO_2 measures for coal-fired power generation and natural gas-fired power generation are JPY 8.9/kWh and JPY 11.6/kWh, respectively. Therefore, based on Table 3 in this paper, when the emissions factor for coal-fired power generation in 2030 is 0.88 tCO_2/MWh and the emissions factor for natural gas-fired power generation is 0.41 tCO_2/MWh, the power generation cost can be calculated by the carbon price for each type of power generation, using the formula below:

$$C_{coal} = 8.9 + P_{carbon} * 0.88/1,000 \qquad \text{(Eq.1)}$$
$$C_{gas} = 11.6 + P_{carbon} * 0.41/1,000 \qquad \text{(Eq.2)}$$

where, C_{coal} denotes cost for coal-fired power generation by carbon price; P_{carbon} denotes Carbon price, C_{gas} denotes cost for gas-fired power generation by carbon price

Carbon prices where coal-fired power generation becomes economically inferior to other power sources were led by simultaneous equation using equation (Eq.1), (Eq.2) and generation cost of renewable energy source. The results are shown in Figure 6. If carbon prices are JPY 2,160/ tCO_2 for general hydropower generation, JPY 2,274/ tCO_2 for geothermal power generation, JPY 4,548/ tCO_2 for solar power generation, JPY 5,582/ tCO_2 for onshore wind power generation, JPY 5,745/ tCO_2 for natural gas-fired power generation, and JPY 7,277/ tCO_2 for residential solar power generation, it is clear that these power sources have an economic advantage over coal-fired power generation.



100JPY≒0.81 USD (as of 29 July 2015)

Figure 6. Evaluation of economic advantages of coal-fired power generation by carbon price

7 Conclusion

There is a large number of coal-fired power plant constructions currently being planned, the total capacity of which amounts up to 18GW. Unrestricted construction of coal-fired power plants may put Japan's long-term transition to a low-carbon economy at risk. This paper analyses the potential impacts of recent construction plans of coal-fired power plants with a total capacity of 18 GW on Japan's mid-term and long-term GHG mitigation targets.

This study first compared the expected CO_2 intensity for power generation in 2030 under current policy plans for Japan, the United States (U.S.) and the European Union (EU). Under the planned electricity mix, the CO_2 intensity for power generation in 2030 is calculated to be 0.36 tCO_2/MWh. Although this is comparable to the CO_2 intensity in the U.S. under its Clean Power Plan (0.34 - 0.38 tCO_2/MWh in 2030), it is higher than that of 0.18 tCO_2/MWh in the EU. Power generation CO_2 intensity values in the U.S. and the EU will rapidly improve towards 2030 and will be within the range projected in 450 ppm CO_2e stabilization scenarios. By contrast, Japan's power generation CO_2 intensity expected for 2030 under the new electricity mix.

The currently planned coal-fired power plant constructions may bring in more coal-fired power than needed under the 2030 electricity mix plan. Under the planned 2030 electricity mix, the amount of electricity generated by coal-fired power plants is calculated at 277 TWh, with CO_2 emissions estimated at 244 $MtCO_2$. However, if plans for the new coal-fired power plants with a total capacity of 18 GW are implemented, the total amount of power supplied from coal-fired power generation in 2030 will be 338 TWh or 32% of the amount of power supplied from all power sources, which will exceed the target of 26% in the 2030 electricity mix. CO_2 emissions are calculated at 291 $MtCO_2$, which is higher than the target of 240 $MtCO_2$. It is possible that the CO_2 intensity could become higher than the planned 2030 electricity mix.

To achieve an 80% reduction of GHG emissions by 2050, as stipulated in the Fourth Basic Environment Plan, GHG emissions in 2050 must be reduced to 247 – 270 $MtCO_2$. However, it will be difficult for Japan to achieve the 2050 targets, as CO_2 emissions from the new coal-fired power plants in 2050 are estimated to be 98 $MtCO_2$ (approximately 36-40% of the GHG emissions cap in the 2050 targets) and emissions from all coal-fired power plants, including existing facilities, are estimated to be 110 $MtCO_2$ (approximately 41-45% of the GHG emissions cap for the 2050 targets). In addition, the results of calculations on the amount of power generated from the implementation of plans for the new coal-fired power plants clearly indicate that that the amount of power generated as estimated in the 2℃ target scenarios deviates widely. This produces a “lock-in effect” where CO_2 emissions remain high for many years.

In order to reduce the intensity in the electricity sector to achieve Japan’s mid- and long-term targets and the 2℃ target scenarios, the revisions of plans for the new coal-fired power plants must be sincerely discussed from the outset with regard to renewables, nuclear power generation as well as CO_2 capture and storage (CCS). If the carbon price exceeds JPY 6,000/tCO_2, the economic advantage of coal-fired power plants can fall in comparison with natural gas-fired power generation and major renewable energies, such as wind and solar power. As actions related to carbon pricing are being promoted through the introduction of carbon taxes and emissions trading by international society, Japan also needs to seriously discuss a framework for the entire power sector.

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